Science News Explores

December 2022/January 2023

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Myths about recycling plastic

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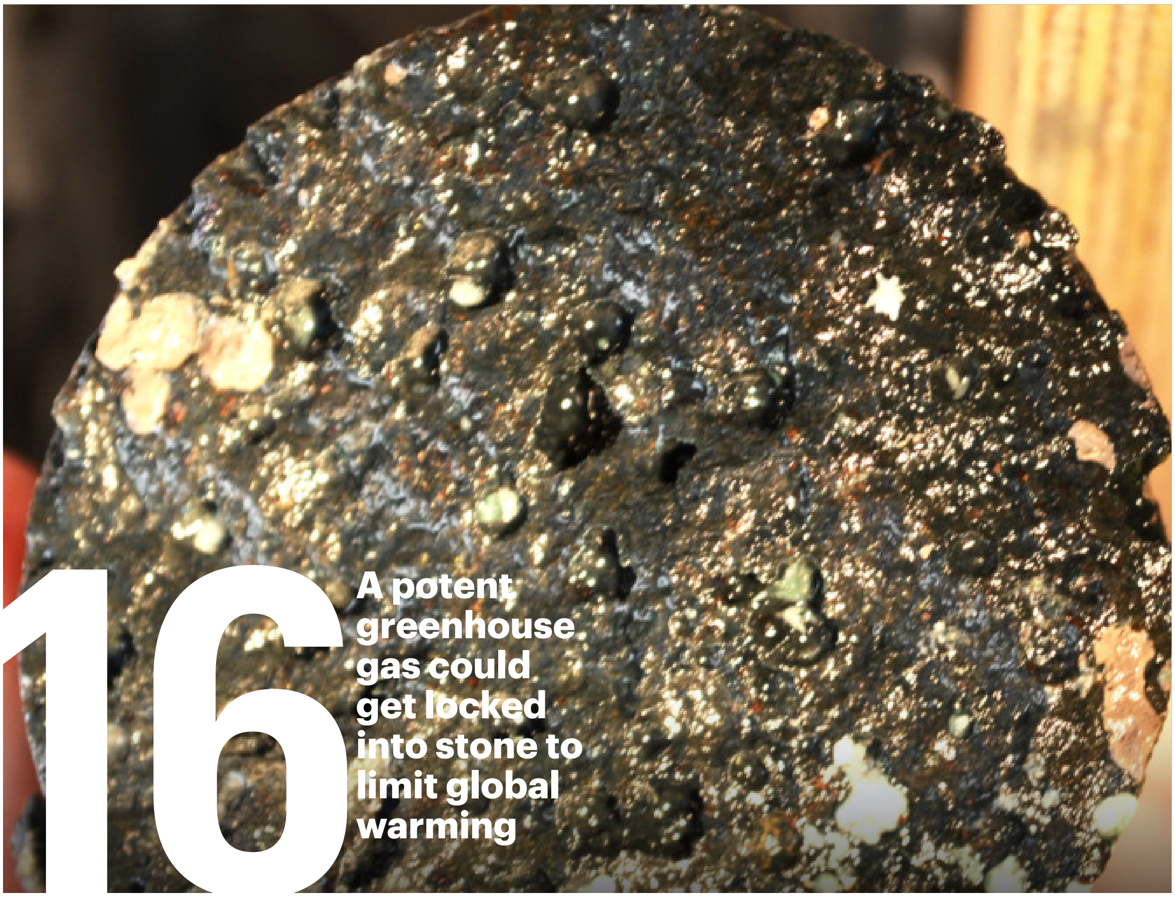

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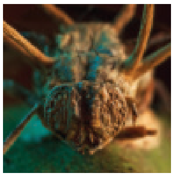

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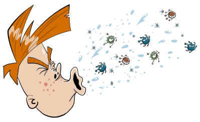

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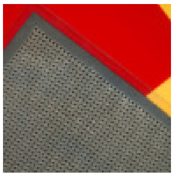

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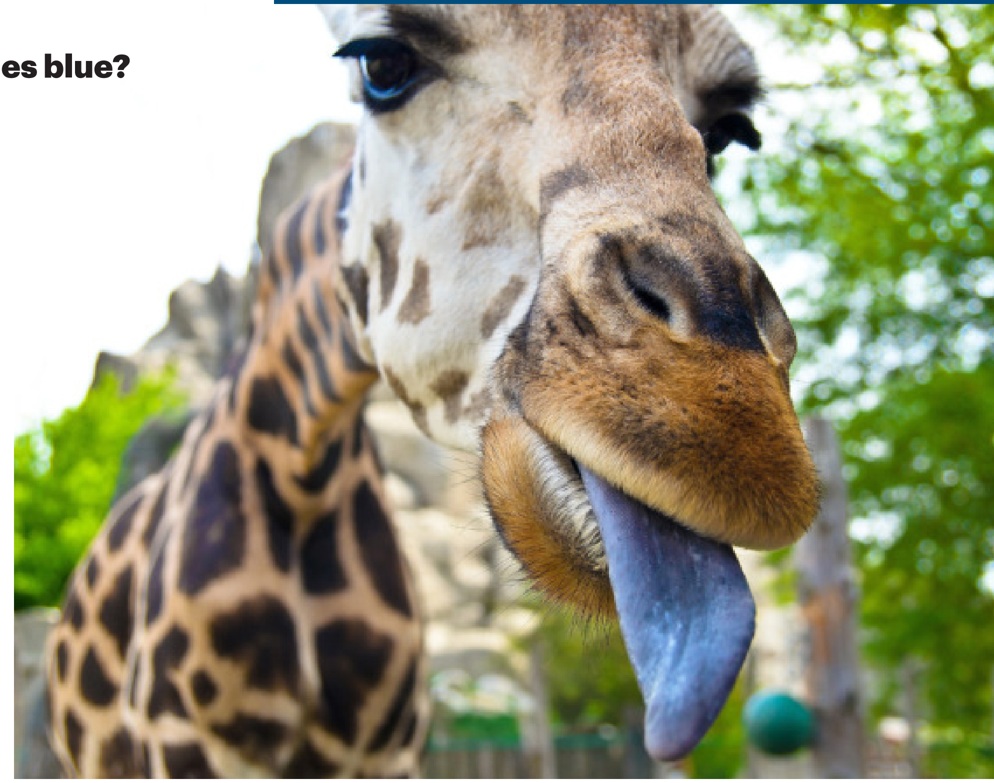


Q Why are giraffe tongues blue?

— Jack K.

A If you get a giraffe to stick out its tongue, that appendage appears blue or dark gray, similar to the tongues of other ruminants. (That's a group of grazing mammals that also includes cows.) Some people thought this dark tongue color evolved from frequent exposure to the sun, since giraffes stick out their tongues to strip leaves off trees to eat. "That is not the case, though," says Graham Mitchell. He's a zoologist and author of *How Giraffes Work*. "It is simply their natural color." If you shaved off a giraffe's spotted fur, you'd see that its skin is dark gray as well.

Q Approximately how many objects are located within the Kuiper Belt?

— Matthew H.

A So far, more than 3,000 objects have been discovered orbiting beyond Neptune. But new ones are being found all the time, says Anne Verbiscer. She's the deputy project scientist for the New Horizons Mission. That NASA mission passed by Pluto in 2015. But the spacecraft continues to collect data on the Kuiper Belt today. According to Verbiscer, the region could contain hundreds of thousands of objects. "There's so many that are too small for us to discover and detect from Earth easily," she says. Astronomers can detect such objects when they pass in front of a distant star. The object blocks out the light of the star as it moves in front of it. This event can be seen even with fairly small telescopes. So it's not only researchers who are discovering new Kuiper Belt objects. "There are lots of amateurs that do this type of work too," says Verbiscer. "Because you don't need a six-meter telescope."

Q How do microwave ovens work?

— Adele V.

A Microwaves are a category of light that lies between radio waves and infrared. Microwave ovens convert electrical power from an outlet into microwaves and use these waves to heat water molecules in your food. The appliance contains a device called a magnetron. It makes microwaves from electricity. The microwaves bounce around inside the cooking chamber until they are absorbed by the food. They don't actually heat your meal directly. Instead, they vibrate water molecules in the food to produce heat. This is different from a conventional oven, which heats up the air. A rotating dish inside the microwave oven can help heat food evenly.

Do you have a science question you want answered? Reach out to us on Instagram (@SN.explores), or email us at explores@sciencenews.org.

Sarah Zielinski
Editor, *Science News Explores*

NATALIIA BUDIANSKA/SHUTTERSTOCK

EARTH

This Pacific tsunami was huge

It was about as tall as the Statue of Liberty

In January 2022, an underwater volcano in the South Pacific underwent an epic eruption. The event packed as much power as a nuclear bomb. It also generated tsunamis around the world. Now it seems that some of those waves may have started out as a single mound of water about as high as the Statue of Liberty!

That's not all. The eruption triggered a huge shock wave in the atmosphere, research shows. That pulse spawned a second set of especially fast-moving tsunamis. Such a rare phenomenon can mess with early warnings of destructive waves. Researchers shared these findings in *Ocean Engineering*.

The volcano behind this drama is named Hunga Tonga–Hunga Ha'apai. It lurks under the ocean in the island nation of Tonga. Its eruption in January launched a large volume of water upward, says Mohammad Heidarzadeh. He's a civil engineer at the University of Bath in England. The water in that mound later "ran downhill" to generate one set of tsunamis.

Heidarzadeh and his colleagues wanted to know just how big that mound of water had been. So his team looked at data from instruments within about 1,500 kilometers (930 miles) of the eruption. The instruments recorded when tsunami waves hit different places. They also showed how big the waves were at each site.

The team used a computer model to compare those data to simulations of the waves an initial mound of water should create. They considered nine simulations. In all, the mound of water was generally shaped like the bump of a baseball pitcher's mound. But each one had a different height and width.

The simulation that best fit real-world data was a mound of water a whopping 90 meters (295 feet) tall and 12 kilometers (7.5 miles) wide. It would have contained about 6.6 cubic kilometers (1.6 cubic miles) of water. That's almost 1,900 times the volume of Louisiana's Superdome stadium.

No question, Heidarzadeh says: "This was a really large tsunami."

Another strange aspect of the Tongan eruption was the second set of tsunamis it triggered. They were caused by a large volume of cold seawater rushing into the hot chamber of magma beneath the erupting volcano.

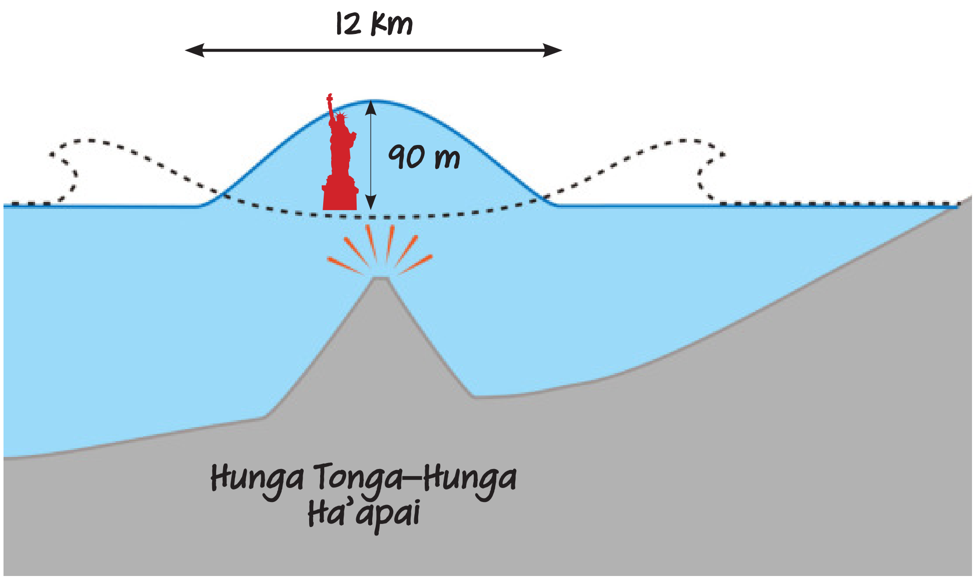
The seawater quickly vaporized. This created an explosion of steam. That blast triggered a shock wave in the atmosphere. This pressure wave raced across the ocean's surface at more than 300 meters per second (670 miles per hour), pushing water ahead of it. The result: more tsunamis.

These tsunamis moved much faster than the ones caused by the collapsing 90-meter pile of water. Along many coastlines, pressure wave–generated tsunamis arrived hours before those other waves. But they were just as big.

Those fast-moving tsunamis from the shock wave came as a surprise. But knowing about them could help researchers improve tsunami-warning systems to account for such superfast waves.

— *Sid Perkins*

January 2022 Tonga Tsunami



Scientists calculated that the initial tsunami wave generated by the underwater Hunga Tonga–Hunga Ha'apai volcano on January 15, 2022, was 12 kilometers wide and about as tall as the Statue of Liberty.

HEIDARZADEH *ET AL*/ *OCEAN ENGINEERING* 2022 (CC BY 4.0)

PSYCHOLOGY

To excel at basketball, it's mind over matter

Elite basketball coaches value psychological traits as a prime game skill

Want to be a great basketball player? You'll need to be fit. Being tall can help. But what interests top coaches most is an athlete's mindset, a new study finds.

Michael Rogers is a PhD student at the University of South Australia in Adelaide. He was part of a team that surveyed 90 basketball coaches from 23 countries for their new study in *Sports Medicine*.

The coaches cited 35 key traits they looked for in elite athletes. Some were physical, such as endurance and speed. Others were psychological. These include attitude, confidence and motivation. In fact, the most prized traits were competitiveness, work ethic and attitude. Coachability and toughness also made the top five. Only one physical trait — agility — made it into the top 10.

Top coaches want players who are "optimistic, easily taught and trained," Rogers says. Great recruits, he adds, are "determined to be more successful and to work harder than others."

These findings don't surprise Timothy Baghurst. He works at Florida State University in Tallahassee. There, he specializes in coaching education. Among similarly fit players, he says, mindset is what will most "define winners and losers." However, he adds, few coaches teach such skills to promote confidence and help control anxiety.

The study was funded by a group seeking basketball players who can help Australia win Olympic medals. But this study could do more than help bring home the gold. The results here offer "a life lesson," says coauthor Grant Tomkinson, also at the University of South Australia. "If you focus on the little things, such as attention to detail, having heart and communicating properly, it can lead to success in all aspects of life."

— *Avery Elizabeth Hurt*

MASTER1305/SHUTTERSTOCK

OCEAN

Sea sponges spew slow-motion snot rockets

The sneezes release debris-filled mucus

Next time you spot a sea sponge, say "bless you!" Some sponges regularly sneeze to clear debris from their bodies.

Sea sponges are simple seafloor creatures. They eat by drawing water in through many holes, or pores, on their surfaces. A system of canals inside the sponge strains that water for nutrients. But the water often contains debris that sponges can't digest.

Now, scientists have discovered how one species keeps that junk from clogging its pores. The Caribbean tube sponge (*Aplysina archeri*) uses mucus to trap and sneeze out unwanted particles. Surprisingly, the sponge blows snot from the same pores through which it absorbs water. Researchers shared this discovery in *Current Biology*.

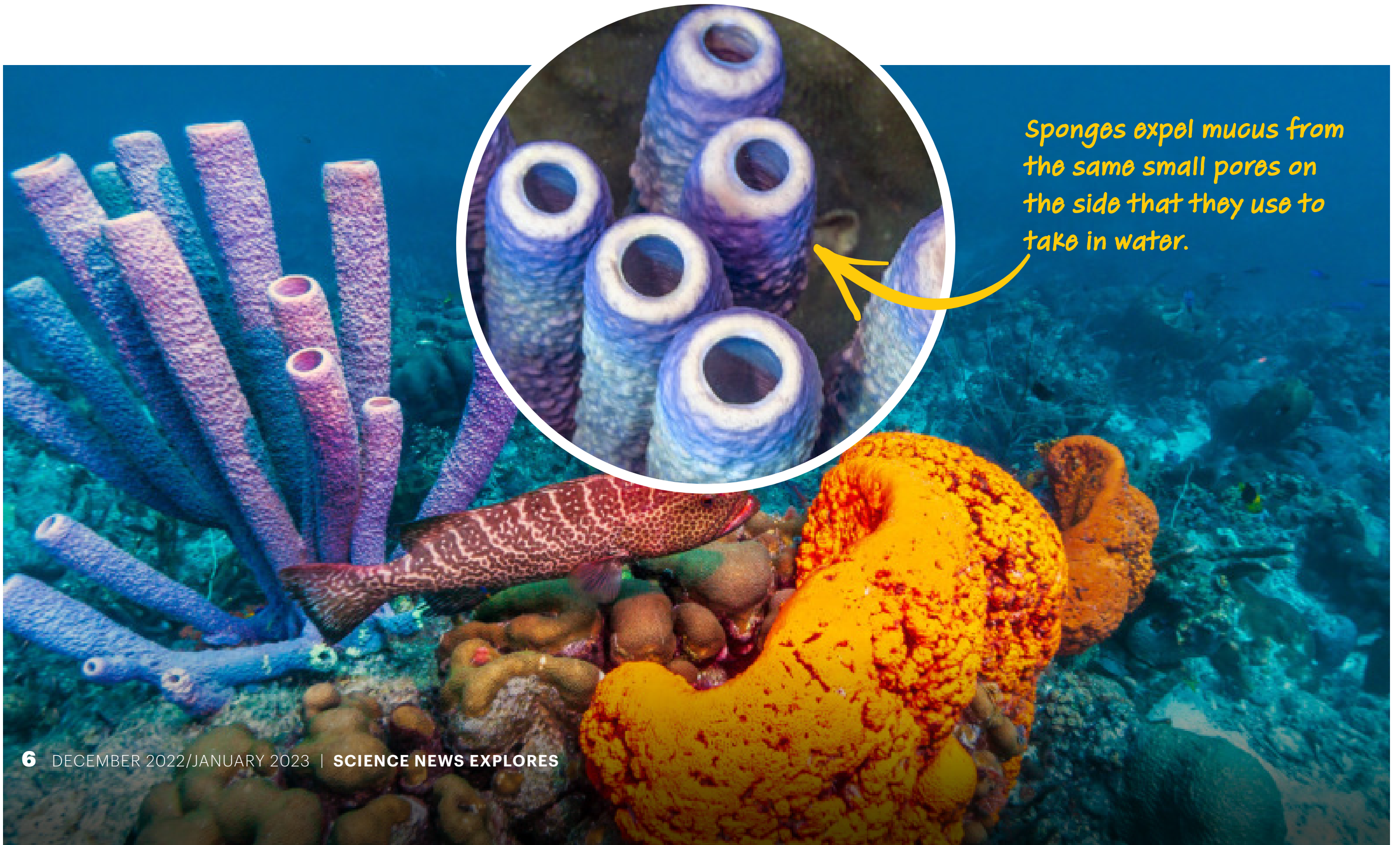
Unlike an explosive human sneeze, sponges continuously release debris-filled mucus. And slowly. Each contraction could last 20 to 50 minutes! It's "like someone with a runny nose," says team member Sally Leys. The sponge's mucus is "constantly streaming." Leys is an evolutionary biologist at the University of Alberta in Edmonton, Canada.

Sea sponges were known to "sneeze." But scientists thought sponges only did this to move water in through the pores and out through a hole near their tops. Time-lapse video now reveals they sneeze tiny specks of mucus through — and against — the flow of incoming water. The resulting "mucus highway" forms stringy, gooey clumps.

Other sea critters feasted on these ocean boogers. So the mucus buffet shows sponges play a key role as providers of food, says Amanda Kahn. This marine biologist was not involved in the study. She works at Moss Landing Marine Labs in California.

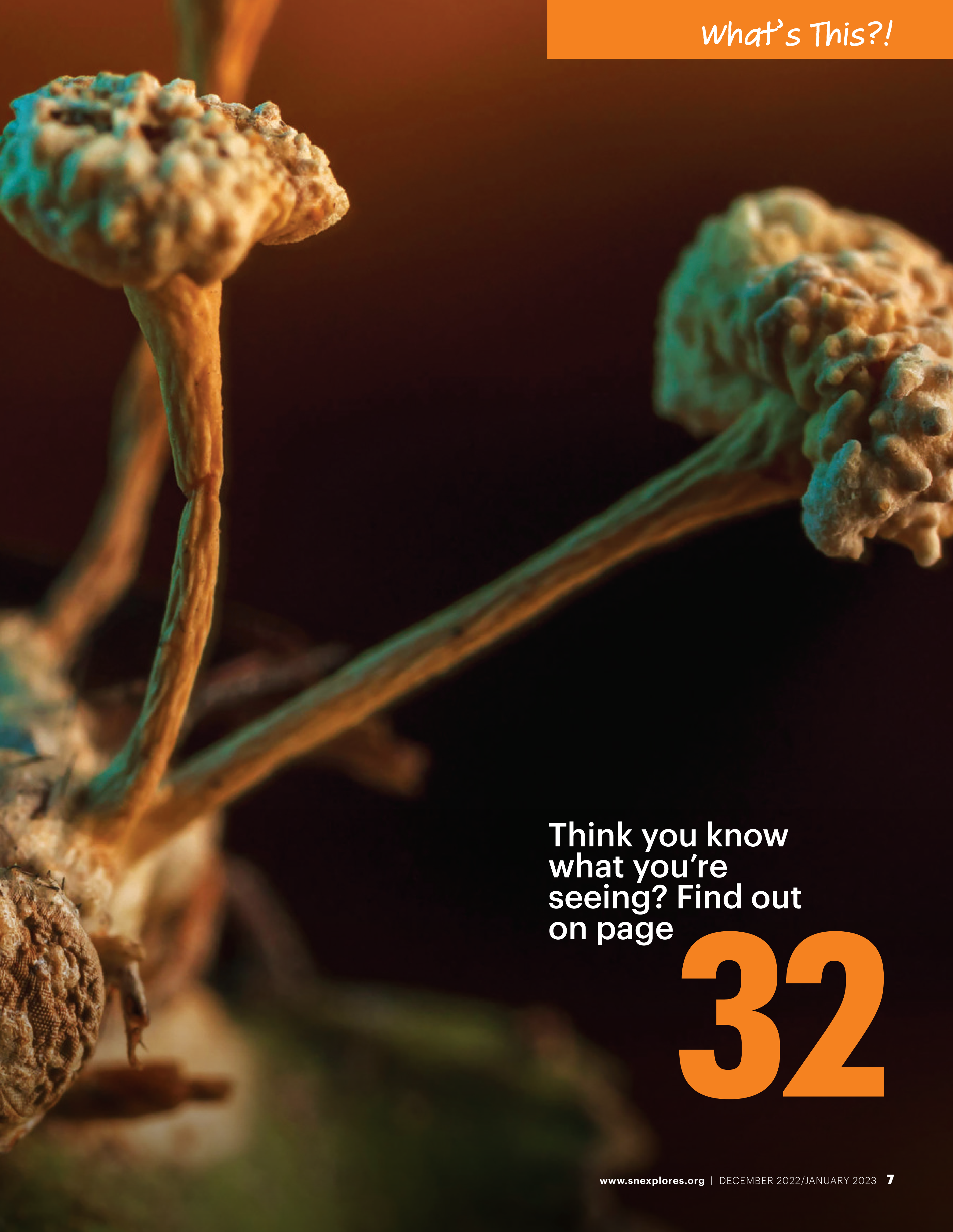
A. archeri probably isn't the only one to sneeze mucus out of its pores, she adds. Her team has seen an Indo-Pacific sponge (*Chelonaplysilla* sp.) do something similar.

— *Jude Coleman*



Sponges expel mucus from the same small pores on the side that they use to take in water.

BOTH: JOHN A. ANDERSON/SHUTTERSTOCK


Think you know what you're seeing? Find out on page 32

By Maria Temming

PLASTIC RECYCLING IS MOSTLY A MYTH

But chemists are working to make it reality >>

It feels good to recycle. When you sort soda bottles and plastic bags from the rest of your garbage, it seems like you’re helping the planet. The more plastic you put in the blue bin, the more you’re keeping out of landfills, right?

Wrong. No matter how much plastic you try to recycle, most ends up in the trash heap.

JASMINKAM/SHUTTERSTOCK

Take flexible food packages. Those films contain several layers, each made of a different type of plastic. Because each type must be recycled separately, those films are not recyclable. Even some items made from only one kind of plastic are not recyclable. Yogurt cups, for instance, contain a plastic called polypropylene. When this gets recycled, it turns into a gross, dark, smelly material. So most recycling plants don't bother with it.

Only two kinds of plastic are commonly recycled in the United States. One is the type used in soda bottles. That's called PET. The other is the plastic in milk jugs and detergent containers. That's high-density polyethylene, or HDPE. Together, those plastics make up only a small fraction of plastic trash. In 2018 alone, the United States landfilled 27 million tons of plastic, according to the U.S. Environmental Protection Agency. A mere 3 million tons was recycled.

Low recycling rates aren't just a problem in the United States. Only 9 percent of all the world's plastic trash has ever been recycled. The rest was burned or has piled up on land or in waterways. Researchers reported those estimates in 2017 in *Science Advances*.

Even when plastic does get recycled, it isn't good for much. Recycling changes the consistency of a plastic. So recycled plastics have to be mixed with brand-new material to make sturdy products. What's more, recycling a bunch of different colored plastic together creates a dark mixture. That means a lot of recycled plastic can only be used to make items whose color doesn't matter, such as benches and dumpsters.

Plastic recycling clearly has a lot of room for improvement. Luckily, chemists around the world are on the case. Some are trying to make it easier to recycle more types of plastic. Others are trying to turn recycled plastic into more useful products. Both strategies could cut how much plastic winds up in landfills or oceans.

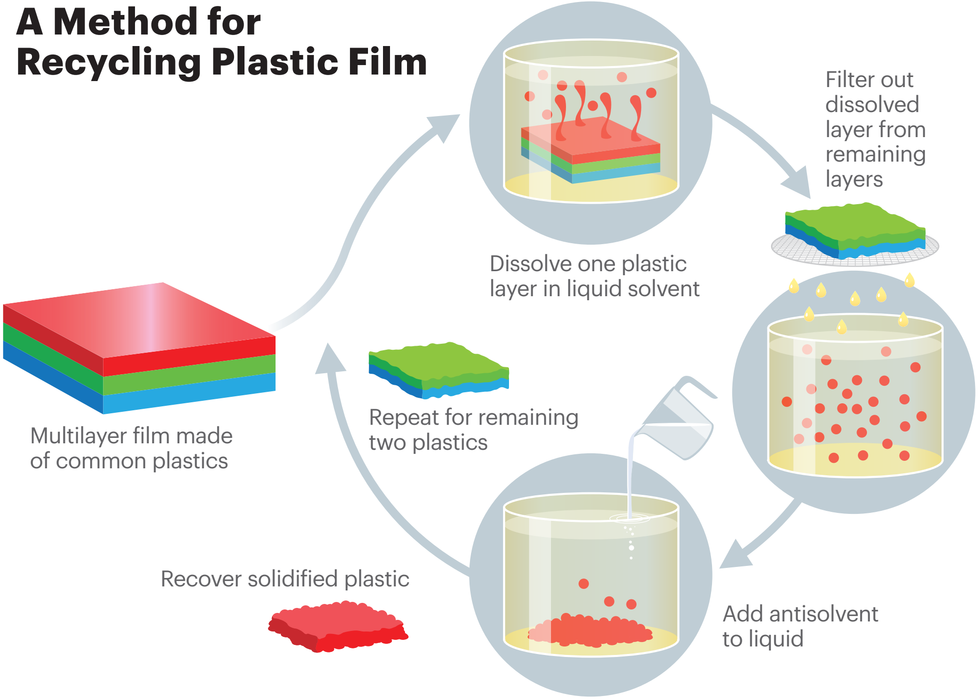
Picking plastics apart

One big challenge to recycling is that every type of plastic must get processed separately. "Most plastics are like oil and water," says Geoffrey Coates. He's a chemist at Cornell University in Ithaca, N.Y. Plastics just don't mix, he says. Take, for example, a detergent container. The jug may be HDPE plastic, but its cap is polypropylene. What would happen if a recycling plant melted those two plastics together and tried to make a new jug from the blend? "It would basically crack down the side," Coates says. "It's crazy brittle. Totally worthless."

That's why all the plastic in the recycling bin first goes to a material recovery facility. There, people and machines sort trash. Sorted plastics are then washed, shredded, melted and remolded. The system works well for simple items like soda bottles and milk jugs. But it doesn't work for items like deodorant containers. A deodorant bottle, cap and crank could all be different plastics.

Food packaging films made of different plastic layers are even harder to take apart. Every year, 100 million tons of these films are made worldwide.

A Method for Recycling Plastic Film


Dissolve one plastic layer in liquid solvent
Filter out dissolved layer from remaining layers
Multilayer film made of common plastics
Repeat for remaining two plastics
Add antisolvent to liquid
Recover solidified plastic

EXPLAINER

The flexible films used to package foods are made of several layers, each containing a different plastic. One method being developed to recycle these films was tested on a film with layers of polyethylene, PET and ethylene vinyl alcohol (EVOH). First, the polyethelene is dissolved in toluene, a solvent. The remaining film of PET and EVOH is pulled out of the solution and set aside. Adding an antisolvent to the solution causes the polyethylene molecules to clump together. This allows them to be fished out of the toluene. The process is repeated with different chemicals to recover the PET and EVOH.

ILLUSTRATION: STEVE MCCRACKEN

Plastic bottles and their tops are often made of different plastics that cannot be recycled together.

Soda and water bottles are usually made of easily recyclable PET plastic. Above, water bottles await processing.

RECYCLING PLANT, BOTTLES, DETERGENT: ALBA_ALIOTH, KONSTANTIN FARAKTINOV, JIANG HONGYAN/SHUTTERSTOCK

Those films all go to landfills, says George Huber. He's a chemical engineer at the University of Wisconsin–Madison.

Huber and his colleagues came up with a way to sort these pesky mixes of plastics. The researchers use different liquids to dissolve different plastic parts off an item one at a time. This strategy was described in 2020 in *Science Advances*.

Huber's team tested the technique on a food-packaging film that contained three plastics: polyethylene, PET and ethylene vinyl alcohol (EVOH). The researchers first stirred the film into a liquid called toluene. That dissolved the polyethylene layer. Then, Huber's team dunked the film in another chemical to strip off the EVOH. The researchers plucked out the remaining PET film. To recover the other two plastics from the liquids, the researchers mixed in "antisolvent" chemicals. These chemicals caused the plastic molecules drifting in the liquids to clump together so that they could be fished out.

Making plastics mix

There may be shortcuts to recycling unsorted mixes of plastics. Chemicals called "compatibilizers" help different plastics blend. Coates' team made one to combine polyethylene and polypropylene. That could make recycling much easier. Those two plastics make up the bulk of the world's plastic trash.

The new compatibilizer contains specially designed molecules. Each molecule has four pieces. Two pieces of polyethylene alternate with two pieces of polypropylene. Those segments latch on to plastic molecules of the same kind in a mixture. It's as if polyethylene were made of Lego blocks, and polypropylene were made of Duplo blocks. The compatibilizer molecule is like a connector that fits both types of blocks. That helps polyethylene and polypropylene molecules link up. The researchers reported this work in 2017 in *Science*.

The first test of this compatibilizer involved using it as a glue. Coates' team spread a layer of the chemical between a strip of polyethylene and a strip of polypropylene. Then, the researchers tried to peel the plastics apart. The two plastics would normally separate easily. But with the glue between them, the plastic strips broke before the seal.

The researchers also mixed their compatibilizer into a melted blend of the two plastics. Adding just 1 percent of the new chemical created a tough plastic product.

Good as new

Making it easier to recycle plastic isn't enough. To reuse the same material over and over, recycled plastic needs to be as good as new. Right now, it's second-rate.

One problem is all the extra chemicals in plastic trash. Plastic items often contain dyes, flame retardants and other add-ons. Current recycling cannot get rid of those contaminants. As a result, recycled plastic comes with lots of impurities. Few manufacturers can use plastic with a random mishmash of properties to make something new.

Plus, recycling breaks some of the chemical bonds in plastic molecules. That affects the strength and consistency of the material. Recycling plastic is sort of like reheating pizza in the microwave. You get out pretty much what you put in, just not as good. That limits the number of times plastic can be recycled.

The solution to both problems could be a new type of recycling, called chemical recycling. This process takes plastic apart at the molecular level. And it could make pure new plastic an infinite number of times.

The molecules that make up plastics are called polymers. Those polymers, in turn, consist of smaller building blocks called monomers. Heat and chemicals can break polymers down into monomers. Those monomers can then be separated from dyes and other contaminants. Piecing pure monomers back together into polymers creates plastic that's good as new.

"Chemical recycling has really started to emerge as a force … within the last three or four years," says Eric Beckman. He's a chemical engineer at the University of Pittsburgh in Pennsylvania. But most chemical recycling requires a lot of energy. "It's not ready for prime time," he says.

Some plastics are easier to chemically recycle than others. "The one that's farthest along is PET," Beckman says. That's the plastic in drink bottles. "That polymer happens to be easy to take apart." Several companies are trying to chemically recycle PET. One is a French company called Carbios.

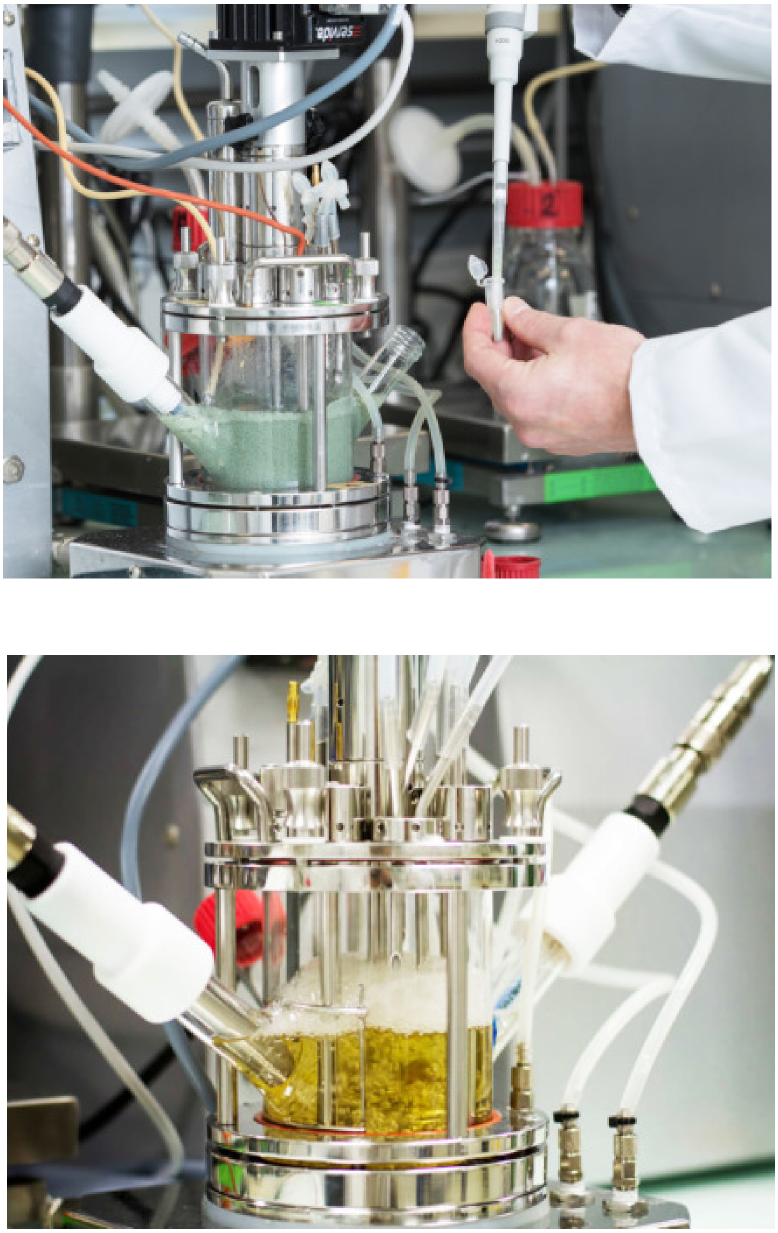
Carbios breaks down PET using a molecule called an enzyme. Microbes in compost naturally produce this enzyme to decompose the waxy coating on leaves. But the enzyme is also good at breaking apart PET. "The enzyme is like a molecular scissor," says Alain Marty. He is the chief scientific officer at Carbios in Saint-Beauzire, France. The enzyme snips PET polymers into their two monomers.

Because this enzyme evolved to decompose leaves, not plastic, it's not perfect. But Marty's team improved it by redesigning its "active site." That's where the enzyme latches onto PET. The redesign involved changing some amino acids at the active site. Marty and his colleagues reported how they did this in *Nature* in 2020.

The researchers tested their upgraded enzyme on plastic flakes from colored PET bottles. About 90 percent of the plastic broke down in about 10 hours. The team purified the PET monomers and used them to make new clear plastic bottles. Those bottles were just as strong as the originals.

Milder conditions

PET is a special case for chemical recycling. Other plastics are much harder to break down. Taking apart polyethylene, for instance, requires temperatures over 400° Celsius (750° Fahrenheit). At such high heat, the chemistry is chaotic. Plastic molecules break down randomly. The result is a jumble of different



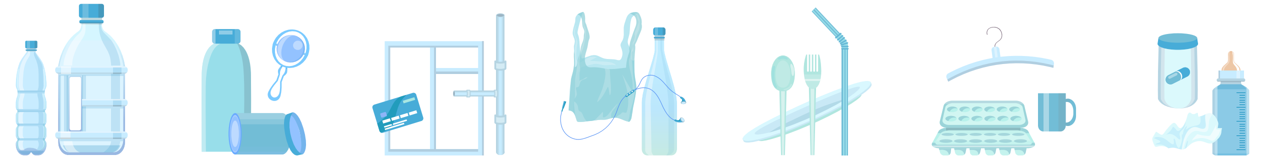
Carbios has developed a chemical recycling process for PET (above) using an enzyme; microbes normally produce the enzyme to decompose the waxy coating on leaves.

CARBIOS

FALSE ADVERTISING

Many plastic products are labeled with a number inside a triangle that symbolizes recycling. Yet, only plastics with **1 (polyethylene terephthalate)** or **2 (high-density polyethylene)** are widely recycled in the United States. The rest typically get buried in landfills.

1	2	3	4	5	6	7
PET	**HDPE**	**PVC**	**LDPE**	**PP**	**PS/EPS**	**O**
Polyethylene Terephthalate	High-Density Polyethylene	Polyvinyl Chloride	Low-Density Polyethylene	Polypropylene	Polystyrene/ Expanded Polystyrene	Other
Water and soft drink bottles, salad domes, cookie trays, salad dressing and peanut butter containers	Milk and juice bottles, freezer bags, shampoo and detergent bottles	Cosmetic containers, commercial cling wrap	Squeeze bottles, cling wrap, trash bags	Microwave dishes, ice cream tubs, yogurt containers, detergent bottle caps	CD cases, plastic disposable cups, plastic cutlery, video cases, foam polystyrene hot drink cups, food takeaway trays, protective packaging for fragile items	Water cooler bottles, flexible films, multimaterial packaging



LEVEL OF DIFFICULTY FOR PLASTIC PROCESSING

🟩 **EASY** 🟦 **POSSIBLE** 🟪 **DIFFICULT** 🟧 **ALMOST IMPOSSIBLE**

Cut this out and place near your recycling bin.

compounds. Those molecules can be burned as fuel but not used to make new plastic.

Susannah Scott proposes a better way to recycle polyethylene. A chemist, Scott works at the University of California, Santa Barbara. Her idea is to break the plastic down under milder conditions. That more-controlled breakdown could produce ingredients for soaps and other products. These ingredients are called alkylaromatic compounds.

To make these, Scott placed polyethylene inside a chamber heated to 280˚ C (540˚ F). Her team cooked the plastic with a powder that contained tiny platinum particles for 24 hours. The platinum helped break the carbon-hydrogen bonds in the polyethylene. That process releases hydrogen. The hydrogen then helped break the plastic's carbon-carbon bonds. This chopped the plastic molecules up into smaller pieces. Each piece was about 30 carbon atoms long. Those fragments arrange themselves into rings. Then voilà — alkylaromatic compounds.

Scott and her colleagues tested this technique on a plastic bag and a bottle cap. Both were made of polyethylene. About 69 percent of the plastic bag became liquid containing alkylaromatic compounds. About 55 percent of the bottle cap was converted. Scott's team reported these results in 2020 in *Science*.

Built to last

Plastics were never designed to be used more than once. That's why recycling them is so hard. But some researchers are now asking, "What does the next generation of materials look like? How do you design a material specifically so that it never has to go into a landfill?" Beckman asks. The new goal, he says, is to design a plastic "that falls apart on command."

A new generation of plastics called PDKs may be infinitely recyclable. They were first described in *Nature Chemistry* in 2019.

"PDKs have the ability to break their bonds under relatively mild conditions," says Brett Helms. He's a chemist at the Lawrence Berkeley National Laboratory in California. Simply dunking a PDK in acid breaks it into its monomers.

The plastic must be dunked in a very acidic liquid to decompose. "It's not like if you put PDKs in vinegar, the polymer is going to start breaking down," Helms says. But it could make for easy recycling. PDK monomers could then be used to make pristine new plastic, again and again.

For now, infinitely recyclable plastic is just a scientific curiosity. But someday, plastics made to be recyclable from the get-go may help solve the world's plastic waste problem.

TARTILA/SHUTTERSTOCK

This chemist uses YouTube to warn about the perils of microplastics

When the pandemic put her plans on hold, Imari Walker found a new way to share her science

If Imari Walker (sounds like "calamari," she jokes) looks familiar, that might be because you came across one of her YouTube videos. There, she talks about two main things: the dangers of plastic pollution and how to prep for college. Walker is a research chemist at the nonprofit organization RTI International in Raleigh, N.C. Her recent PhD, though, focused on plastic pollution and how microplastics get into our environment. Microplastics are tiny bits of plastic that come from deteriorating products and waste.

She first got interested in the issue of plastic pollution in college. She started to think about its impacts on us and other organisms, as well as the whole environment. And she wanted a career where she could work on cleaning up the problem. Now Walker is co-writing a book for high schoolers and college students. It covers topics such as the history of plastic production and alternatives to address the plastic pollution problem. In this interview, she shares her experiences and advice with *Science News Explores*. (This interview has been edited for content and readability.) — *Aaron Tremper*

Q How did you get to where you are today as a science communicator?

A I think it started kind of slow. The catalyst was actually the pandemic in 2020 when my PhD was just about halfway done. All the conferences and plans that I had to share my science got canceled. I needed a different way to continue to put my research out there. I thought a YouTube channel would be a really great way to do that. And I thought that plastic pollution was an issue the rest of the world should know about.

Q What would you say is one of your biggest successes?

A If we're talking about the YouTube channel, I think it would have been the "10 Facts You Need to Know About Microplastics" video. That one provides people with some really easy facts about what microplastics are and what they could possibly be doing to our environment.

> "Take your time to enjoy yourself as much as possible. It's so easy to try and go for everything in the world and try to be everything to everyone."

Imari Walker (inset, with her cat Poppy) is a research chemist and science communicator working to make people aware of the risks posed by tiny bits of plastic pollution.

I. WALKER

Q What do you like to do in your spare time?

A I'm learning how to play the piano. I love reading. That's always something that kind of takes me away and makes me think about the wide world around us. I think playing with my cat is always great.

Q What piece of advice do you wish you had when you were younger?

A Take your time to enjoy yourself as much as possible. It's so easy to try and go for everything in the world and try to be everything to everyone. But it's really good to value your peace and your time. And just in general, make time for enjoying your life.

Q What would you say to someone who is considering a career in STEM?

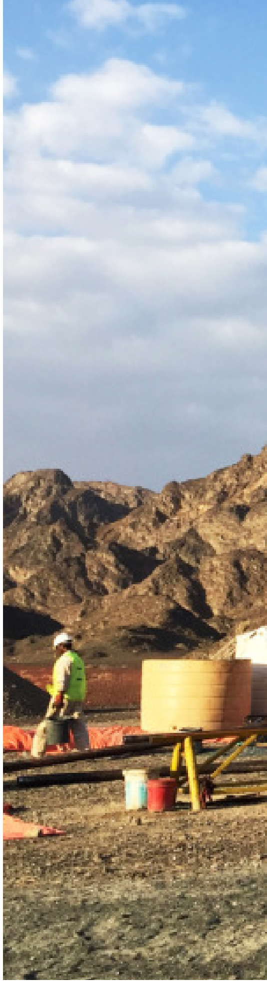
A The sky's the limit in that you can do just about anything that you want to do. It's okay, though, if you don't like a particular type of science, even if it's a part of the prerequisites to finish a degree. At the end of the day, it's about getting the overall degree and getting into the career that you really enjoy. ◗

A BOLD PLAN *TO SAVE THE* PLANET

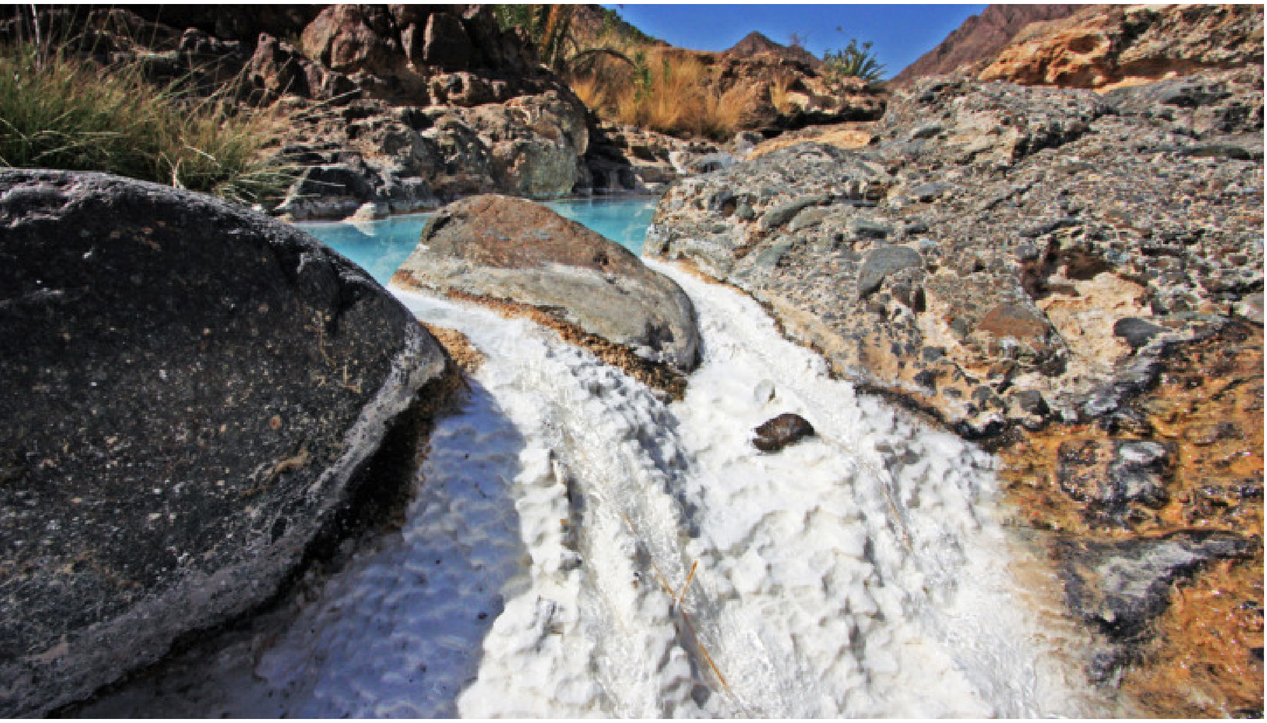
By Douglas Fox

Turning carbon dioxide into stone could help limit global warming >>

LUKAS BISCHOFF PHOTOGRAPH/SHUTTERSTOCK



The tired, crumbling peaks of the Al-Hajar Mountains in the desert nation of Oman are slowly decomposing like a slab of rotten meat. Subtle signs of decay are all around. Flammable hydrogen gas sometimes bubbles from groundwater. Water from natural springs is often saturated with minerals. This water leaves a carpet of frosty white crystals as it flows over the ground.



When rain falls, it trickles into cracks in the rock, carrying gases from the air with it. The water and gases react with the rock to form new, colorful minerals. These jagged veins of black, white and blue-green minerals push their way into the bedrock. Like slow but powerful fingers, the minerals widen the cracks, prying the rock apart.

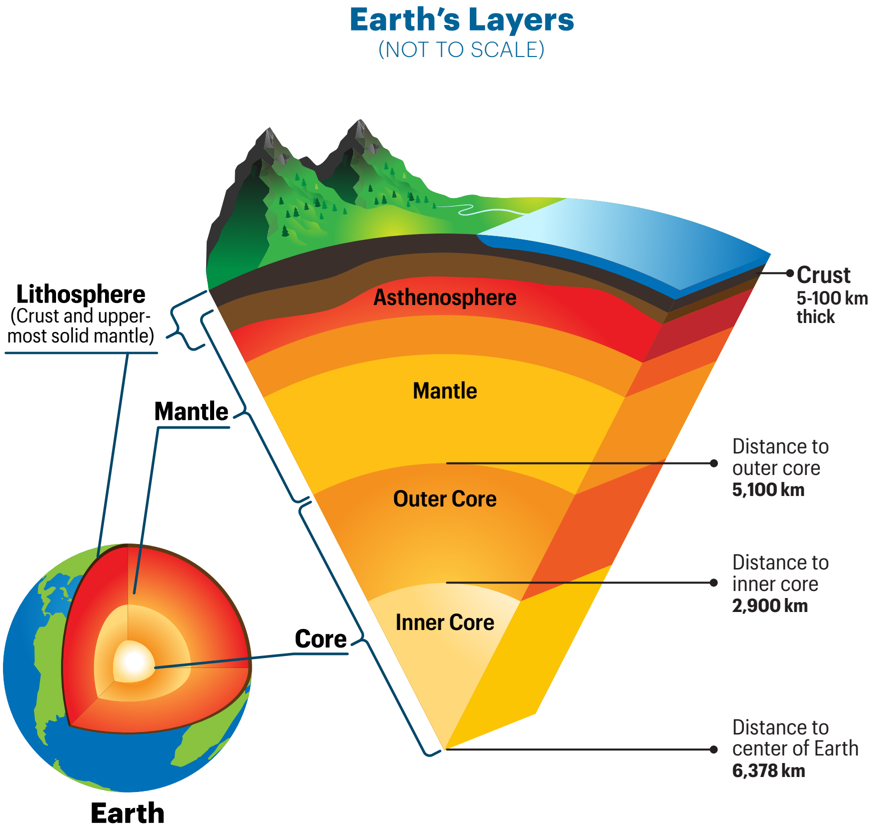
Peter Kelemen believes that these decomposing rocks could help humans solve an important problem: climate change.

Kelemen is a geologist at the Lamont-Doherty Earth Observatory in Palisades, N.Y. The white carbonate veins, he says, were formed as carbon dioxide (CO_2) in rainwater latched onto magnesium and calcium atoms in the rocks. Carbon dioxide is the same gas that humans release when they burn fossil fuels. It's the same greenhouse gas that is warming our planet.

These rocks in Oman, a nation east of Saudi Arabia, are petrifying 50,000 to 100,000 tons of CO_2 per year, Kelemen believes. That's puny compared to the 30 billion tons of CO_2 that humans release each year. But Kelemen and his colleagues believe these rocks could one day be used to solidify up to a billion tons of CO_2 per year. Other rock formations scattered around the world could capture another 10 billion to 20 billion tons of CO_2 each year. "You're looking at something that

At these alkaline springs in Oman, water emerges from the ground saturated with dissolved calcium, which quickly reacts with CO_2 in the air, forming carpets of calcium carbonate crystals.

D. FOX



Earth's Layers

(NOT TO SCALE)

Workers drill into the ground (above) in Wadi Lawayni, a remote valley in Oman. Millions of years ago, unusual rocks were pushed to the surface here through a rare geologic upheaval. Now in contact with the air, they are reacting with carbon dioxide, locking the greenhouse gas into solid minerals.

JUERG MATTER/UNIV. OF SOUTHAMPTON; ILLUSTRATION: VECTORMINE/SHUTTERSTOCK

could potentially have an impact on the human global carbon budget," he says.

Kelemen and his collaborator, Juerg Matter, have been working on this idea for nearly 20 years. Matter is a geochemist at the University of Southampton in England. When I visited them in Oman in 2018, their team was there to get samples of rock from as deep as 400 meters (1,300 feet) underground. Those samples would help them better understand a natural process that they hope to speed up.

Negative emissions

Removing CO_2 from the air once seemed outlandish. In the last 20 years, however, it has gained momentum as the urgency of climate change has become clearer.

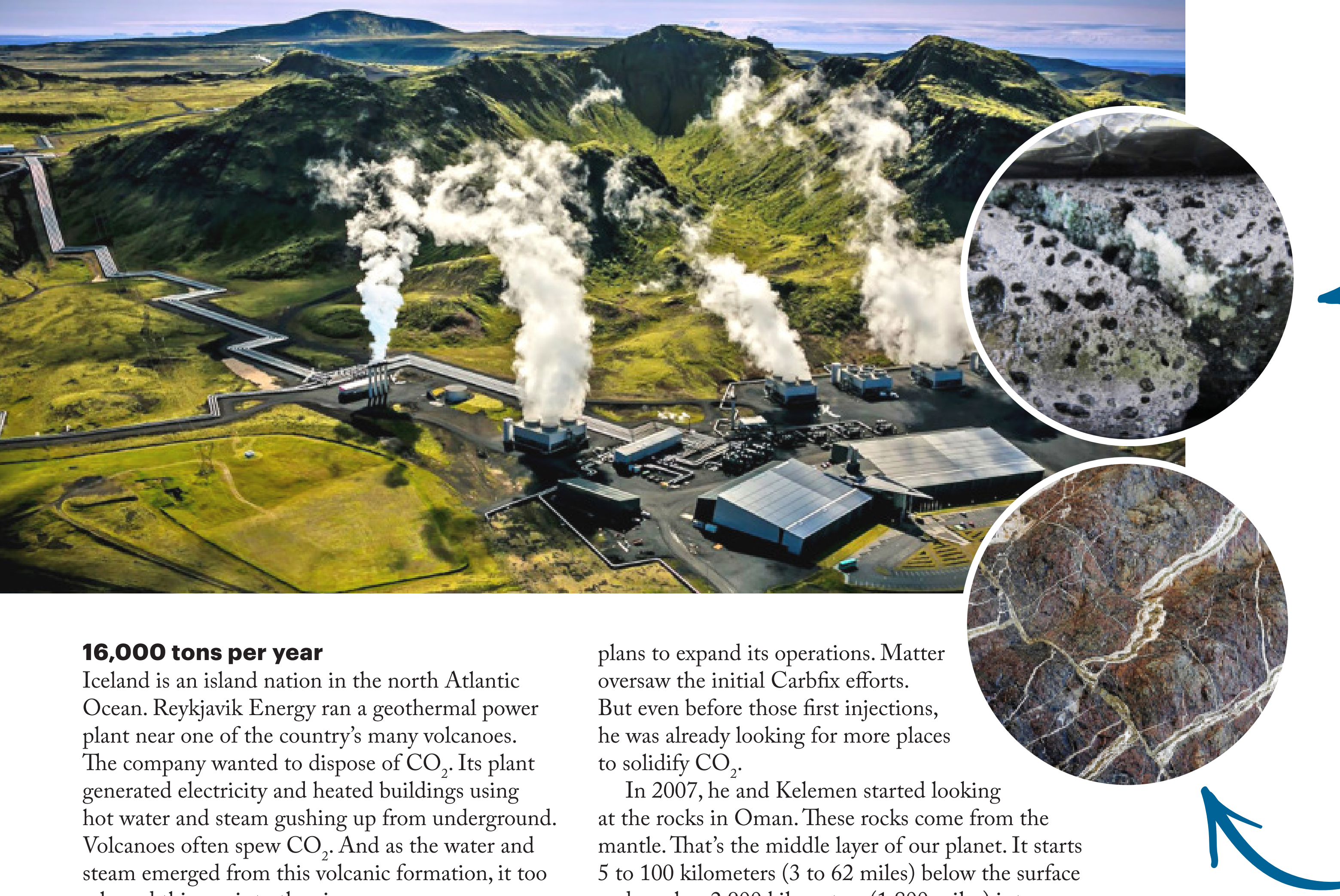
Many scientists now believe people will not reduce releases of greenhouse gases quickly enough to prevent Earth from warming more than 1.5 degrees Celsius (2.7 degrees Fahrenheit). It is thought that this warming limit would avert the most dangerous effects of climate change. Those effects include runaway sea level rise, the loss of the Amazon rainforest and frequent catastrophic storms.

Some scientists are now suggesting that people resort to a strategy called "negative emissions." These would include vast projects to suck, or "capture," CO_2 from the air. They would need to use many tactics, such as replanting forests or fertilizing the ocean to spur the growth of photosynthetic plankton. The forests and plankton would naturally pull CO_2 out of the air.

Several companies are also building "direct air capture" machines to pull CO_2 from the air. The captured gas could then be pumped underground.

Energy companies have pumped small amounts of CO_2 into empty oil and gas reservoirs since the 1980s. There, the gas is trapped between layers of sedimentary rocks, such as sandstone. Some observers fear that the gas could leak back out.

But different rocks, like those in Oman, could more permanently trap CO_2. They contain high levels of calcium and magnesium silicates. In these minerals, calcium and magnesium atoms are bound to clusters of oxygen and silicon atoms, called silica. These minerals, uncommon at Earth's surface, are plentiful in rocks very deep below ground. Scientists had suspected these minerals would react with CO_2 and lock it into carbonate minerals. This idea lured Matter to get involved. And in 2012 he got the chance to test it, in Iceland.



At this geothermal plant and Carbfix site (above) near Hengill Volcano in Iceland, volcanic CO_2 that emerges with hot water is injected back into the basalt rock to lock away the CO_2 in carbonate minerals.

PLANT: ÁRNI SÆBERG, CARBFIX; TOP CLOSEUP: SANDRA SNÆBJÖRNSDÓTTIR, CARBFIX; BOTTOM CLOSEUP: KATIE PRATT, DEEP CARBON OBSERVATORY/WIKIMEDIA COMMONS (CC BY-SA 2.5)

16,000 tons per year

Iceland is an island nation in the north Atlantic Ocean. Reykjavik Energy ran a geothermal power plant near one of the country's many volcanoes. The company wanted to dispose of CO_2. Its plant generated electricity and heated buildings using hot water and steam gushing up from underground. Volcanoes often spew CO_2. And as the water and steam emerged from this volcanic formation, it too released this gas into the air.

But there was an obvious solution. Iceland is made almost entirely of basalt. This type of rock forms when lava erupts out of volcanoes and cools. Because it comes from deep inside the Earth, it holds high amounts of calcium and magnesium silicates. Injecting CO_2 into that basalt should lock it away.

The experiment began in early 2012. Workers opened a valve and injected water 400 to 800 meters (1,300 to 2,600 feet) down into the basalt below. This water held five times as much CO_2 as seltzer water does. To prevent it from fizzing violently as the gas escaped, the water had to be kept under high pressure. Over three months, the team injected 175 metric tons (193 U.S. tons) of CO_2 into the rock.

More than 95 percent of the CO_2 formed solid minerals within two years. "It happened actually faster than we dared to hope," says Sandra Snæbjörnsdóttir. She's a geologist who worked on this project, known as Carbfix.

The team drilled a new hole and retrieved stone cores from near the injection site. The cylinders of gray-black basalt were splotched with white. Those splotches were the carbonate minerals formed by the injected CO_2.

Carbfix is now petrifying 16,000 tons of CO_2 per year. And it has become a separate company, with plans to expand its operations. Matter oversaw the initial Carbfix efforts. But even before those first injections, he was already looking for more places to solidify CO_2.

In 2007, he and Kelemen started looking at the rocks in Oman. These rocks come from the mantle. That's the middle layer of our planet. It starts 5 to 100 kilometers (3 to 62 miles) below the surface and reaches 2,900 kilometers (1,800 miles) into the Earth. The Oman rocks were a tiny fragment of mantle shoved up to the surface millions of years ago.

The mantle is the source of lava and basalts. Its rocks contain even higher levels of calcium and magnesium than do basalts. Because of this, Matter and Kelemen believed that the Oman rocks might be able to trap even more CO_2 per cubic meter than the rocks in Iceland.

The two scientists needed to learn about what was happening below the surface. So in 2017 and 2018, they and a large team of researchers drilled several holes in Oman to retrieve stone cores. I spent a week with them in January 2018 as they drilled in a remote valley, Wadi Lawayni.

Veins of many colors

On a late afternoon, several camels wandered past, chewing on scraggly bushes. A diesel engine roared. And a metal drill shaft, driven by that engine, spun several thousand times per second as it cut into the rocks beneath our feet.

Now and then, workers in hard hats idled the motor to a low growl. Then they raised the drill from the hole, detached a metal pipe and slid out three meters (9.8 feet) of cored rock. The cylinders of stone were as thick as a baseball bat.

CO_2 that is injected into basalts at Carbfix is rapidly solidified into white calcium carbonate minerals, as shown in this drill core.

White carbonate veins crisscrossing this mantle rock in Oman were one of the signs that CO_2 could be trapped in stone.

The gray stone was crisscrossed with white, black, orange-yellow and blue-green minerals. These veins marked where water and gases, seeping through cracks, had reacted with the stone.

Oxygen reacted with iron in the rock — essentially rusting it — to create yellow and orange veins. Black, blue and green veins often were a mineral called serpentine. It forms when water reacts with silicates. And the white veins were usually carbonate minerals. The core samples confirmed what Matter had long suspected. “All of the CO_2 is mineralized in the very shallow part,” he says. Once rainwater has seeped in, it may spend many years underground. But all of its CO_2 is consumed right at the beginning, in the top 100 meters of rock.

Matter and Kelemen now think the rate of carbonate formation in these rocks could be boosted — and by a lot. Someday, they envision CO_2 being pressurized into water at 124 times rainwater’s natural concentration, or about six times that of seltzer water. This mix would then be pumped three kilometers (almost two miles) underground. Rocks there are close to 100° C (212° F). The high heat and pressure would speed up the chemical reactions that turn CO_2 to stone.

This is many years away, but the first baby steps are starting. In 2020, an Omani company named 44.01 was set up. (It is named after the average weight of a molecule of CO_2.) The company’s goal is to trap CO_2 in rocks in Oman.

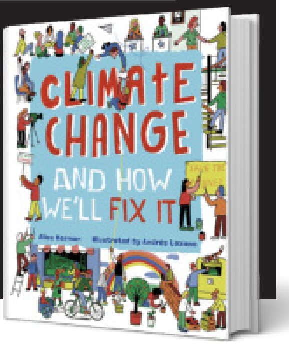
“We are aiming for one gigaton,” said Talal Hasan, shortly after 44.01 was formed. He is the company’s founder. By “gigaton,” he means a billion tons per year.

Read More

Climate Change and How We’ll Fix It

—by Alice Harman

Looking to help the environment but unsure of where to start? Learn how you can make a difference in this no-nonsense, illustrated guide to climate change.



THE QUARTO GROUP

But the long-term success of that vision will depend on more than just scientific results. It will also depend on the decisions of governments around the world. Governments will need to require companies pay money to dispose of the CO_2 that they emit.

The cost of turning CO_2 to stone

Companies like 44.01 and Carbfix can only turn CO_2 to stone if someone will pay them to do it. And before CO_2 can be injected underground, it first has to be captured from the air. The tech to capture CO_2 is not cheap.

Even if someone is willing to pay for it, turning CO_2 into stone will require a lot of work. Companies like Carbfix and 44.01 might take decades to work their way up to injecting gigatons of CO_2 per year. And the operations needed to do that will be truly massive.

Kelemen estimates that trapping a billion tons of CO_2 per year in Oman might require 5,000 injection wells. Those wells would need to pump a combined 23 cubic kilometers of water into the ground each year. That’s equal to nearly one third the annual flow of the Missouri River — one of the largest rivers in the United States. Because Oman is a desert nation, this water would have to come from the ocean.

Gathering a billion tons of CO_2 per year from the air would require thousands of machines, each about the size of a truck. Together, they could devour up to 1.3 trillion kilowatt hours of electricity per year. That’s three times the amount of electricity consumed by the entire state of Texas. To avoid gushing more CO_2 into the air, this electricity would need to come from a renewable source, such as wind or solar.

The Intergovernmental Panel on Climate Change (IPCC), which is run by the United Nations, has estimated how much CO_2 would need to be captured in order to limit warming to 1.5 degrees Celsius. By 2050, people would need to remove up to 20 billion tons of CO_2 from the skies each year. That would require 20 of these massive operations, like the one that Hasan envisions in Oman, working across the globe. Or it would mean hundreds of smaller ones.

These are all big challenges. But Ajay Gambhir, an energy economist at Imperial College London in England, views technologies to capture and lock up CO_2 as an important “insurance policy.” Perfecting them will take years. But if we get to 2040 and CO_2 emissions are still high, then it will be too late at that point to start working on them, he says. “Doing it now is the right thing to do.” ◗

HEALTH

Snot science

How far does a sneeze travel?

By Bethany Brookshire

No one wants to get COVID, a cold or the flu. Vaccines for COVID and flu may help you to avoid the worst symptoms. But no matter how much you try to protect yourself, it seems someone nearby is sneezing. Those sneezes spray out tiny drops of mucus, in which viruses can hide. Sometimes it's a fine spray. Other times, thick snot gets everywhere. How far does each kind of snot travel? And how far away do you have to stand to stay safe from viral spread?

HYPOTHESIS

Thin snot will fly farther and spread more than thick snot.

METHOD

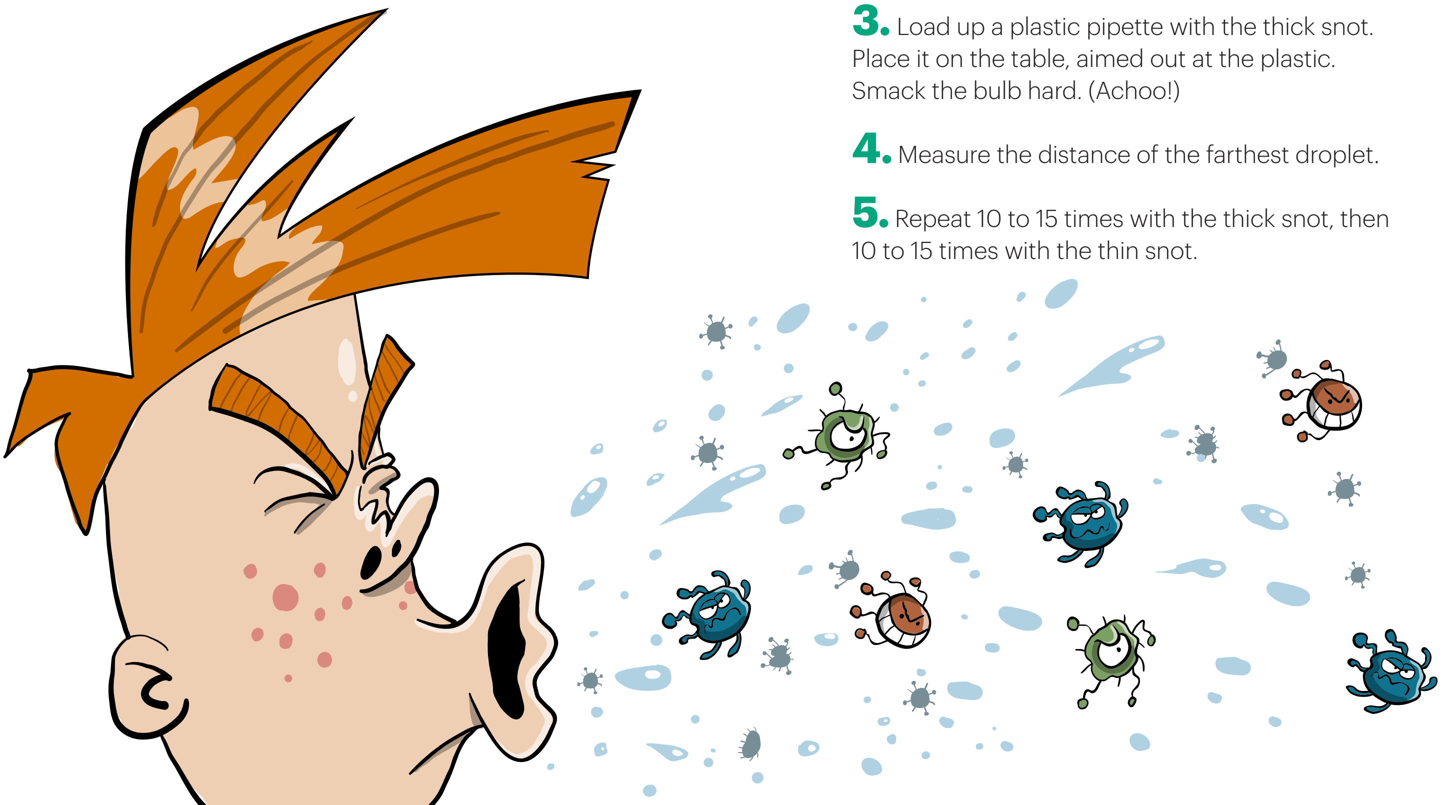
1. In a large room, place a table at one end and line the floor with white plastic or shower curtains. Mark out lines every half meter (about 20 inches) on the plastic, starting at the table. You will want to have at least three meters of space.

2. Create thick and thin snot using our recipe online (see link below).

3. Load up a plastic pipette with the thick snot. Place it on the table, aimed out at the plastic. Smack the bulb hard. (Achoo!)

4. Measure the distance of the farthest droplet.

5. Repeat 10 to 15 times with the thick snot, then 10 to 15 times with the thin snot.



SCC.COMICS/SHUTTERSTOCK

DID YOUR DATA SUPPORT YOUR HYPOTHESIS?

Find the snot recipes, how to analyze your data and more at www.snexplores.org/snot-science

These words are hiding in this issue. Can you find them?

The words below came from the stories in this magazine. Find them all in the word search, then search for them throughout the pages. Some words will appear more than once. Can you find them all? Check your work by following the QR code at the bottom of the page.

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CARBON
DOLPHIN
DYE
ELECTRICITY
FLY
FUNGUS
GEOLOGIST
GIGATON
GIRAFFE
GREENHOUSE
MEMBRANE
MICROWAVES
MINERAL
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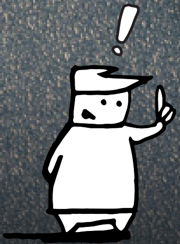


PATPITCHAYA/SHUTTERSTOCK

TECHNOLOGY

You might someday ‘wallpaper’ your bedroom with this loudspeaker

Super-thin speakers could bring noise-canceling tech to large spaces

Noisy siblings? Loud construction right outside your window? A new flexible loudspeaker could help you rest easy. It could someday turn your walls into noise-canceling systems. And when you’re ready to liven things up, use the same wallpaper — or the surfaces of other ordinary objects in your room — to play music.

The new loudspeaker is about as thick as a few sheets of paper. It’s lightweight and flexible enough to stick to most surfaces. It also produces high-quality sound. And you can make it big, as in wall-sized, notes Jinchi Han. He’s an electrical engineer at the Massachusetts Institute of Technology in Cambridge.

At the heart of most speakers are moving membranes. An electric current makes them vibrate quickly. That sends nearby air molecules moving — and generating sound waves. Those vibrating air molecules are “the working principle for sound generation,” explains Han.

The new speakers don’t use such membranes. Instead, lots of dome-shaped microstructures cover their surface. When squeezed, the material creates an electric charge. Such materials are known as piezoelectric. Applying an electric field across the material will cause the domes to expand and contract, Han explains. That can vibrate nearby air molecules, generating sound.

Because the design is so flexible and durable, companies could potentially integrate speakers into T-shirts or other personal items. Or users could make their own. Han and his colleagues describe their innovation in *IEEE Transactions on Industrial Electronics*.

YOU CAN PUT THESE SPEAKERS ANYWHERE

Old-style piezoelectric speakers broadcast sound waves through the motion of the whole speaker. Mounting such speakers onto a solid surface, Han says, would hamper their sound by restricting that motion.

Han’s team sandwiches their new material between two plastic sheets to protect the domes. Tiny holes punched through the sheets line up in such a way that the domes can expand into these holes as they vibrate.

“The bottom layer elevates the small domes so that they can vibrate freely even if the speaker is mounted on a surface,” Han reports. They can vibrate even if the surface is rough or curved. The upper protective layer “is thicker than the domes are high,” he explains. So he notes that if you touch the surface, “you don’t need to worry about damaging these small structures.”

Han points to another benefit of this tech. Large expanses of the new material could make controlling noise a whole lot easier.

Most noise-canceling systems detect sound waves in the environment and then generate new sound waves to “cancel” those out. Whether it works for a listener depends on where that listener’s ears are in relation to the approaching sound waves.

Trying to cancel noise this way everywhere inside a room would be tricky, Han points out. It would take lots of microphones and speakers, which can be bulky and expensive.

Here, each dome works as a tiny speaker. The domes can generate sound waves all together, in groups or individually. Wallpapering your bedroom with this material would create speakers all around you. Those same speakers also could dampen — or cancel — unwanted sound. When desired, you could turn any space into “a quiet zone where you could sleep or study without too much noise,” Han says. He also sees applications in cars, airplanes, apartments or anywhere unwanted noise is a problem.

Another plus? The new design costs far less and uses less energy than conventional speakers.

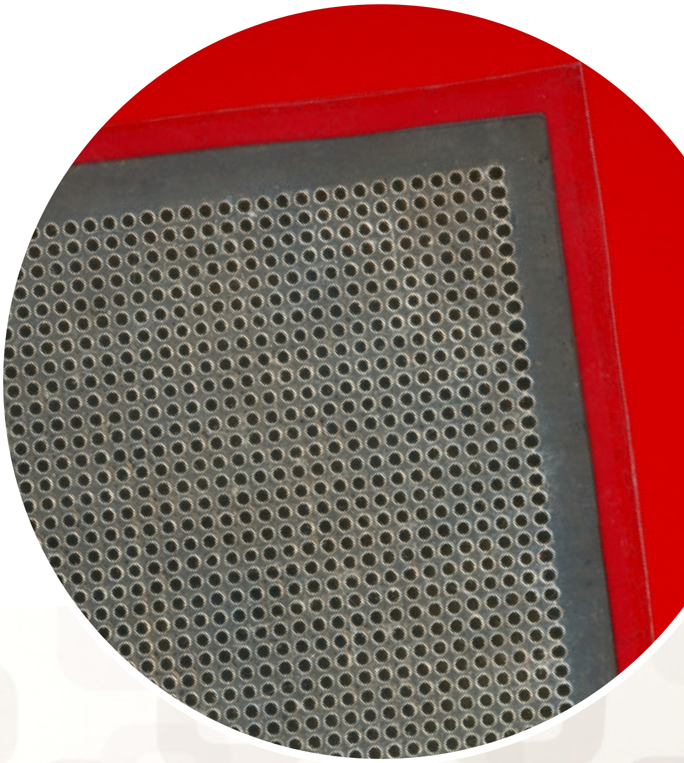
The researchers built a prototype — a sheet of the material that's 10 centimeters by 10 centimeters (about 4 inches by 4 inches). The piece has more than 8,000 domes. Super-sizing the design would be straightforward, Han says.

Large versions could be the next step for immersive, or 3-D, sound experiences, says Lori Beckstead. She teaches audio and digital media at Toronto Metropolitan University in Ontario, Canada. She's also a sound artist.

In an immersive sound experience, sounds seem to come from all directions. Such designs can help people fully engage in performances, virtual-reality scenarios, museum exhibits and other experiences. The new speakers are so thin and light they "could be placed in spaces where traditional loudspeakers might have been impractical," Beckstead adds.

And that doesn't just apply to immersive sound. She notes that adding noise-canceling technology to loud spaces — from restaurants to noisy manufacturing plants — would be fantastic. "Poorly designed sound environments can be detrimental to anything from mental health to productivity to mood."

— *Kendra Redmond*



This thin, flexible loudspeaker (right) generates sound waves with tiny, vibrating domes. So those domes can vibrate freely, they are layered between thin plastic sheets covered in holes. One day this might be embedded in wallpaper (below).

BOTTOM: PIKSELSTOCK/SHUTTERSTOCK; TOP: FELICE FRANKEL

Splatoon's ink ammo was inspired by cephalopods

Octopuses and squids shoot ink too — but mostly to defend, rather than attack

In Nintendo's *Splatoon* games, rising sea levels have killed off most land dwellers, and sea creatures now reign. Kids known as Inklings and Octolings can transform into squids and octopuses, and they duke it out with weapons that spew ink. This thick, colorful goo is used to paint over buildings and the ground. Real-life squids and octopuses shoot out ink, too. But how does the ink of *Splatoon*'s rowdy kids compare?

For one thing, squids, octopuses and other cephalopods have built-in ink shooters. These soft-bodied animals use special muscles to draw water under the main part of their body, known as the mantle. This oxygen-rich water passes over the gills and lets the animals breathe. The water is then expelled through a tube known as a siphon. Cephalopods can also use this funnel to squirt ink.

These inks don't come in the technicolor hues of the Inklings. Octopus ink tends to be solid black, while squid ink is more of a bluish-black, says Samantha Cheng. This squid biologist is director of conservation evidence at World Wildlife Fund in Portland, Ore. Other cephalopods called cuttlefish produce a dark brown ink often referred to as "sepia." Cephalopod inks get their dark color from a pigment called melanin. This is the same substance that helps make up your skin, hair and eye color.

As ink moves through a cephalopod's siphon, mucus can be added. The more mucus added to the ink, the stickier it becomes. Cephalopods can use inks of different thicknesses to defend themselves in different ways.

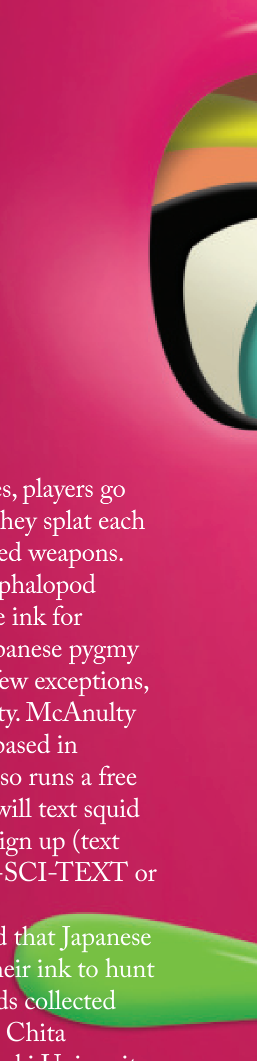
"If a cephalopod is feeling like there's a predator nearby, or they need to make a quick getaway, they can release their ink in different forms," says Cheng.

An octopus spews its famous smoke screen by adding just a dab of mucus to its ink. That makes the ink very runny and able to spread out easily in water. This creates a dark veil that allows the octopus to escape unseen. Some cephalopod species, however, can add more mucus to create smaller clouds of ink called "pseudomorphs." These dark blobs are meant to look like other octopuses and distract predators. Other cephalopods can add more mucus to craft long threads of ink that resemble seagrass or jellyfish tentacles.

These inkings serve as more than just a distraction, though. A squirt of ink from a threatened cephalopod can alert others of the same species to possible danger. Cephalopods use special sensory cells called chemoreceptors to pick up on the signal, Cheng says. "They have chemoreceptors that are specifically tuned to the contents in the ink."

GOING HUNTING

In the *Splatoon* series, players go on the offensive as they splat each other with ink-loaded weapons. In contrast, most cephalopod species on Earth use ink for self-defense. The Japanese pygmy squid is one of the few exceptions, says Sarah McAnulty. McAnulty is a squid biologist based in Philadelphia. She also runs a free phone hotline that will text squid facts for users that sign up (text "SQUID" to 1-833-SCI-TEXT or 1-833-724-8398).



Scientists learned that Japanese pygmy squids use their ink to hunt by studying 54 squids collected from around Japan's Chita Peninsula. At Nagasaki University, researchers gave these super small squids three species of shrimp to hunt. The teeny hunters were observed taking down shrimp with their ink 17 times. Thirteen of these attempts were successful. Researchers shared the results in 2016 in *Marine Biology*.

The scientists reported two types of hunting strategies. Some squid shot a puff of ink between themselves and the shrimp before grabbing the shrimp. Others squirted ink away from their prey and ambushed from another direction. That's some impressive planning for a creature the size of a pinky nail.

Whether they're tricking a potential predator or taking down a tasty shrimp, cephalopods rely

POLYNOMIALCHAOS

on moving water to help disperse their ink and give it shape. Having enough space also prevents the squid from sucking up its own ink. “The ink can clog their gills,” McAnulty says. “They basically suffocate from their own ink.”

McAnulty appreciates how the Japanese *Splatoon* series is bringing squid awareness to an international audience. “There isn’t enough squid in art depicted in the United States in my opinion,” says McAnulty. “So, anytime there’s a squid, I’m happy.”
— *Aaron Tremper* ◗

Octopus ink tends to be solid black, a big contrast from the colorful inks in the video game.

ILLUSTRATION BY STEVE MCCRACKEN

EARTH

A guide to greenhouse gases

Carbon dioxide is just one of several chemicals that contribute to the greenhouse effect

Earth's atmosphere is a mix of gases. Nitrogen accounts for 78 percent. Oxygen, in second place, makes up another 21 percent. Many others account for the remaining 1 percent. Several, such as helium and krypton, are chemically inert. That means they don't react with others. But other bit players have the ability to act like a blanket for the planet. These have come to be known as *greenhouse gases*.

Like the windows in a greenhouse, these gases trap energy from the sun as heat. Without them, Earth would be quite frosty. Global temperatures would average around –18° Celsius (0° Fahrenheit). Instead, the surface of our planet averages around 15° C (59° F), making it a comfy place for life.

Since about 1850, though, human activities have been releasing extra greenhouse gases into the air. This has slowly propelled a rise in average temperatures across the globe. Overall, the 2021 global average was 0.85 degree C (1.51 degrees F) higher than it had been between 1951 and 1980. That's based on calculations by NASA.

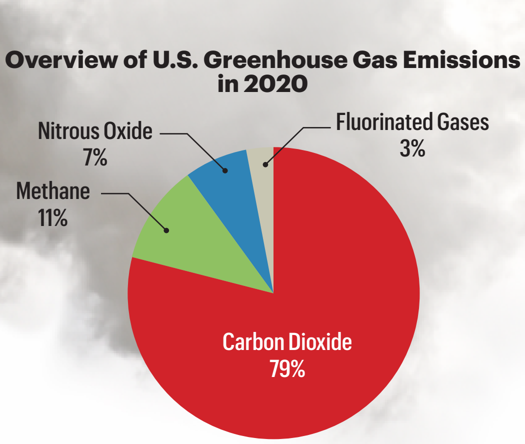
Stephen Montzka is a research chemist with the National Oceanic and Atmospheric Administration (NOAA) in Boulder, Colo. There are four main greenhouse gases to worry about, he says: carbon dioxide, methane, nitrous oxide and a group that contains chlorofluorocarbons (CFCs) and their replacements. CFCs are refrigerants that have played a role in thinning the planet's protective high-altitude ozone layer. They are being phased out as part of a global agreement begun in 1989.

Many chemicals influence climate. They include water vapor, aerosols and more. However, Montzka notes, these four greenhouse gases are the ones "that we [humans] have direct control over." That's why people care so much about how much of them human society emits.

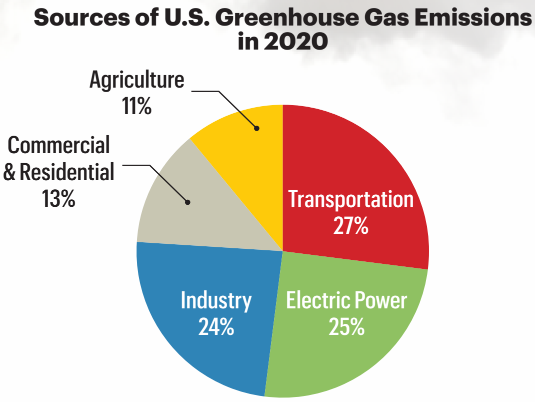
— *Sarah Zielinski*

Carbon dioxide

Excess carbon dioxide (CO_2) comes mainly from burning fossil fuels — coal, oil and natural gas. Those fuels are used for everything from powering vehicles and generating electricity to manufacturing industrial chemicals. In 2020, CO_2 accounted for 79 percent of the greenhouse gases emitted in the United States. Other chemicals are more effective at trapping heat in the atmosphere. But CO_2 is the most abundant of the ones released by human activities. It also sticks around longest. It can linger in the atmosphere for anywhere from decades to thousands of years. So, Montzka explains, "even if we stopped emitting carbon dioxide today, we would still see warming from that for a very long time."



Overview of U.S. Greenhouse Gas Emissions in 2020

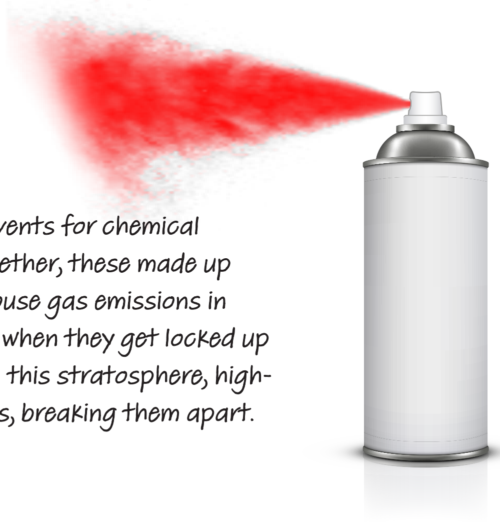


Sources of U.S. Greenhouse Gas Emissions in 2020

PIE CHARTS: U.S. ENVIRONMENTAL PROTECTION AGENCY (2022), INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS: 1990-2020; SMOKE: TRANCEDRUMER/SHUTTERSTOCK

Methane

Methane is the main component of natural gas. It's also released from a host of biological sources. These include rice production, animal manure, cow digestion and the breakdown of wastes put into landfills. Methane accounts for about 11 percent of U.S. greenhouse-gas emissions. Each molecule of this gas is much better at trapping heat than is one of CO_2. But methane does not remain in the atmosphere as long, sticking around for only about a decade.



CFCs

CFCs and their more recent replacements are all manufactured by people. Many have been used as refrigerants. Others are used as solvents for chemical reactions and in aerosol sprays. Together, these made up only about 3 percent of U.S. greenhouse gas emissions in 2020. These gases are only removed when they get locked up in a high layer of the atmosphere. In this stratosphere, high-energy light bombards the chemicals, breaking them apart. But that can take decades.

Nitrous oxide

Nitrous oxide (N_2O) made up 7 percent of U.S. greenhouse gases in 2020. This gas comes from agriculture, the burning of fossil fuels and human sewage. But don't let its small quantity make you disregard N_2O's impact. This gas is hundreds of times more effective than is CO_2 at trapping heat. N_2O also can linger in the atmosphere for more than a century.

COWS: STACIE SHOEMAKER/SHUTTERSTOCK; HAIRSPRAY: SAM72/SHUTTERSTOCK; REFRIGERATOR: FOTOVIKA/SHUTTERSTOCK; TRACTOR: VLADIMIR YA/SHUTTERSTOCK

Bulky plesiosaurs may not have been bad swimmers

Large size may have compensated for odd body shapes

Plesiosaurs prowled the ancient seas back during the age of dinosaurs. With broad bodies and often lanky necks, these ancient reptiles (which weren't dinosaurs) didn't look like they'd be swift swimmers. But new analyses suggest they might have been.

Their shapes greatly differed from sea creatures today, notes Susana Gutarra Díaz. She's a biologist who worked on the study when she was at the University of Bristol in England. Some plesiosaurs were the size of small dolphins. Others were as big as buses. The necks on some could be up to three times as long as their torsos. Given their

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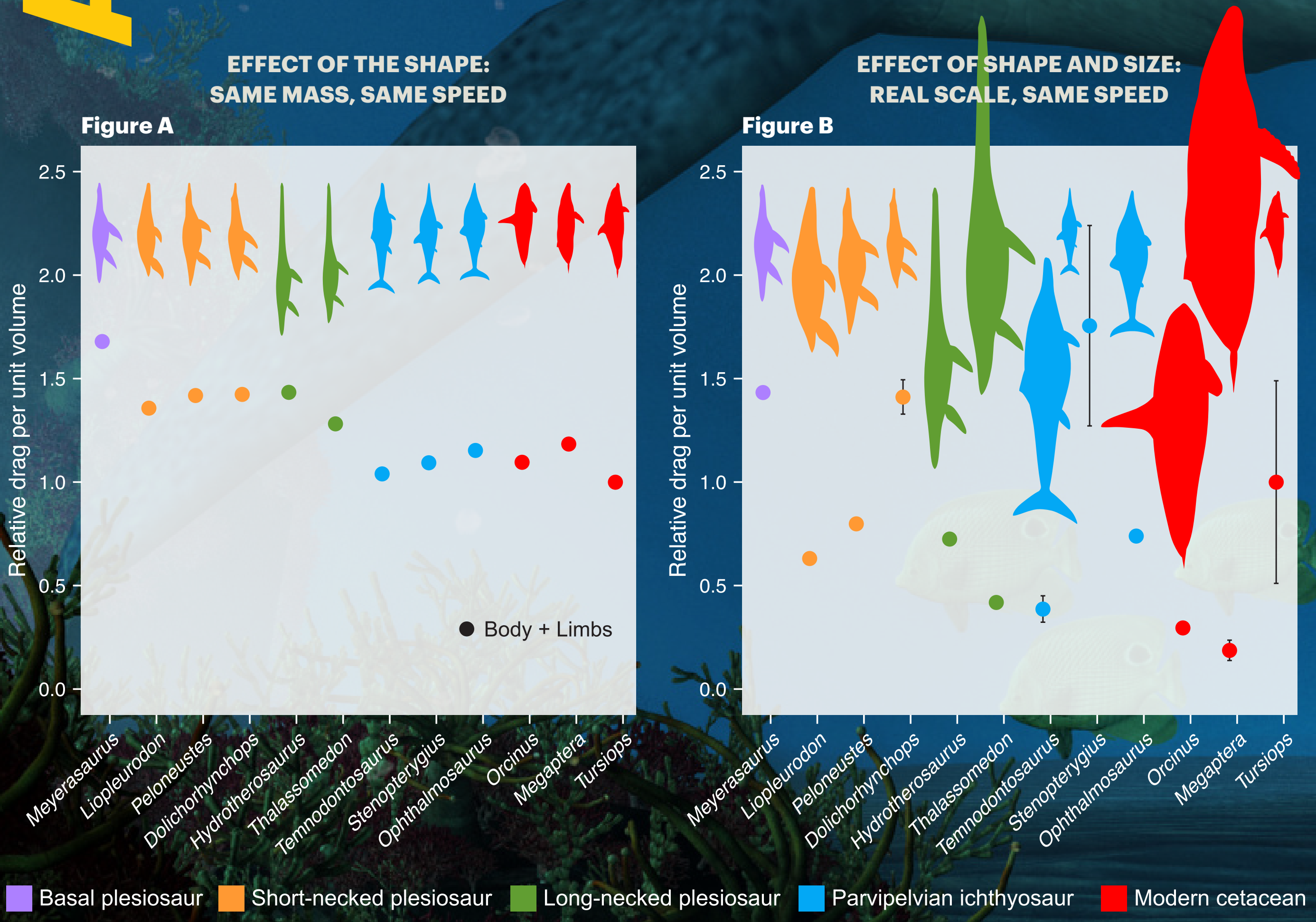
WHAT A DRAG

Using a computer program, researchers compared how water flows around the bodies of different animals, creating drag. These graphs show that drag force, which resists motion, for each virtual animal. Figure A shows the drag per unit volume when the animals are all assumed to be the same size. Figure B shows the drag per unit volume when the animals are their actual sizes.



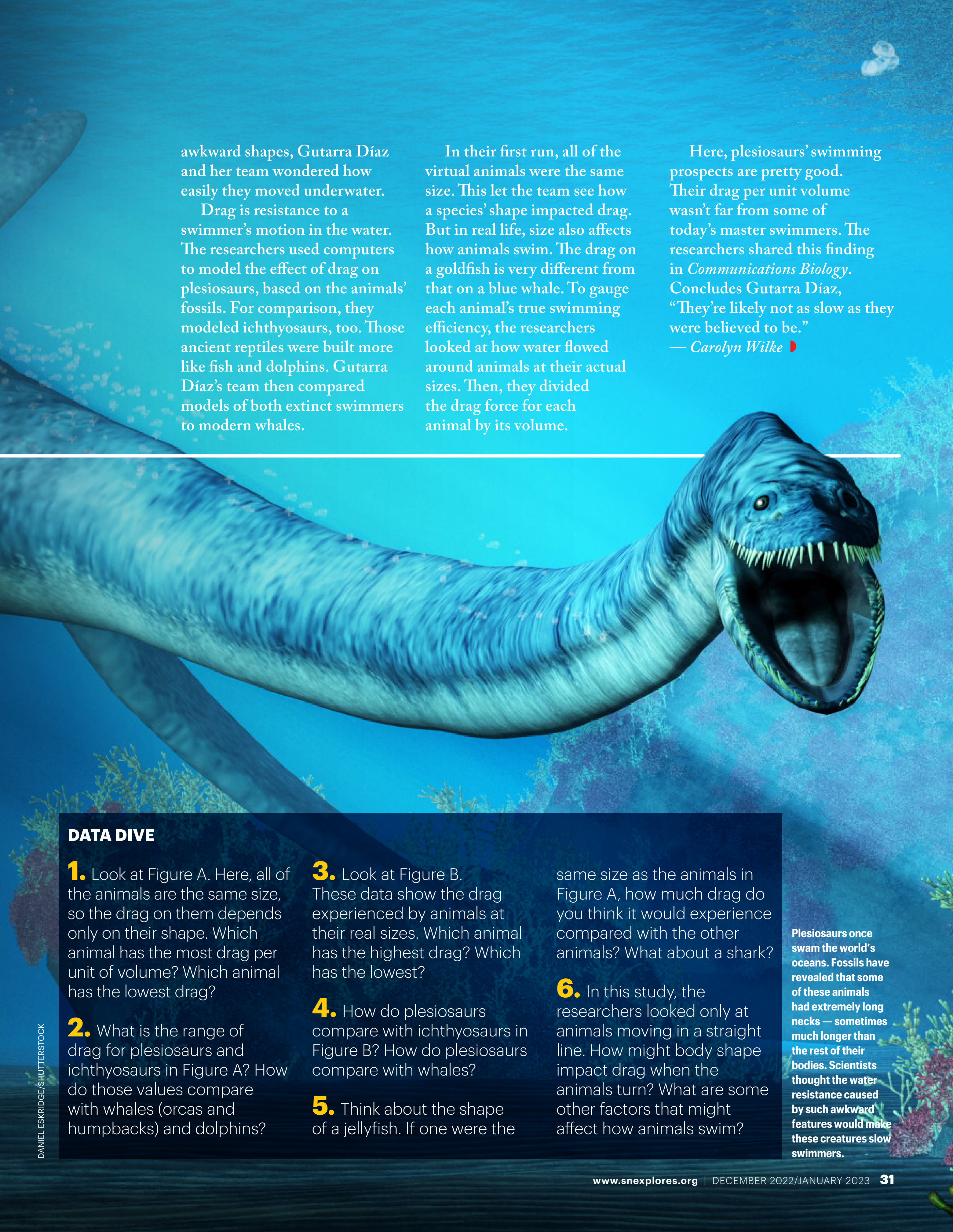
S. GUTARRA ET AL/COMMS. BIOL. 2022 (CC BY 4.0); ADAPTED BY L. STEENBLIK HWANG

awkward shapes, Gutarra Díaz and her team wondered how easily they moved underwater.

Drag is resistance to a swimmer's motion in the water. The researchers used computers to model the effect of drag on plesiosaurs, based on the animals' fossils. For comparison, they modeled ichthyosaurs, too. Those ancient reptiles were built more like fish and dolphins. Gutarra Díaz's team then compared models of both extinct swimmers to modern whales.

In their first run, all of the virtual animals were the same size. This let the team see how a species' shape impacted drag. But in real life, size also affects how animals swim. The drag on a goldfish is very different from that on a blue whale. To gauge each animal's true swimming efficiency, the researchers looked at how water flowed around animals at their actual sizes. Then, they divided the drag force for each animal by its volume.

Here, plesiosaurs' swimming prospects are pretty good. Their drag per unit volume wasn't far from some of today's master swimmers. The researchers shared this finding in *Communications Biology*. Concludes Gutarra Díaz, "They're likely not as slow as they were believed to be."
— *Carolyn Wilke*



Plesiosaurs once swam the world's oceans. Fossils have revealed that some of these animals had extremely long necks — sometimes much longer than the rest of their bodies. Scientists thought the water resistance caused by such awkward features would make these creatures slow swimmers.

DANIEL ESKRIDGE/SHUTTERSTOCK

DATA DIVE

1. Look at Figure A. Here, all of the animals are the same size, so the drag on them depends only on their shape. Which animal has the most drag per unit of volume? Which animal has the lowest drag?

2. What is the range of drag for plesiosaurs and ichthyosaurs in Figure A? How do those values compare with whales (orcas and humpbacks) and dolphins?

3. Look at Figure B. These data show the drag experienced by animals at their real sizes. Which animal has the highest drag? Which has the lowest?

4. How do plesiosaurs compare with ichthyosaurs in Figure B? How do plesiosaurs compare with whales?

5. Think about the shape of a jellyfish. If one were the same size as the animals in Figure A, how much drag do you think it would experience compared with the other animals? What about a shark?

6. In this study, the researchers looked only at animals moving in a straight line. How might body shape impact drag when the animals turn? What are some other factors that might affect how animals swim?

ANSWER

This award-winning photo reveals a 'zombie' fungus erupting from a fly

It captures the cycle of life and death in the Amazon rainforest

Sometimes a photo is literally a matter of life, death — and zombies.

This haunting image is the winner of the 2022 *BMC Ecology and Evolution* photography competition. It captures the fruiting bodies of a parasitic fungus. They are emerging from the lifeless body of an infected fly in the Peruvian rainforest.

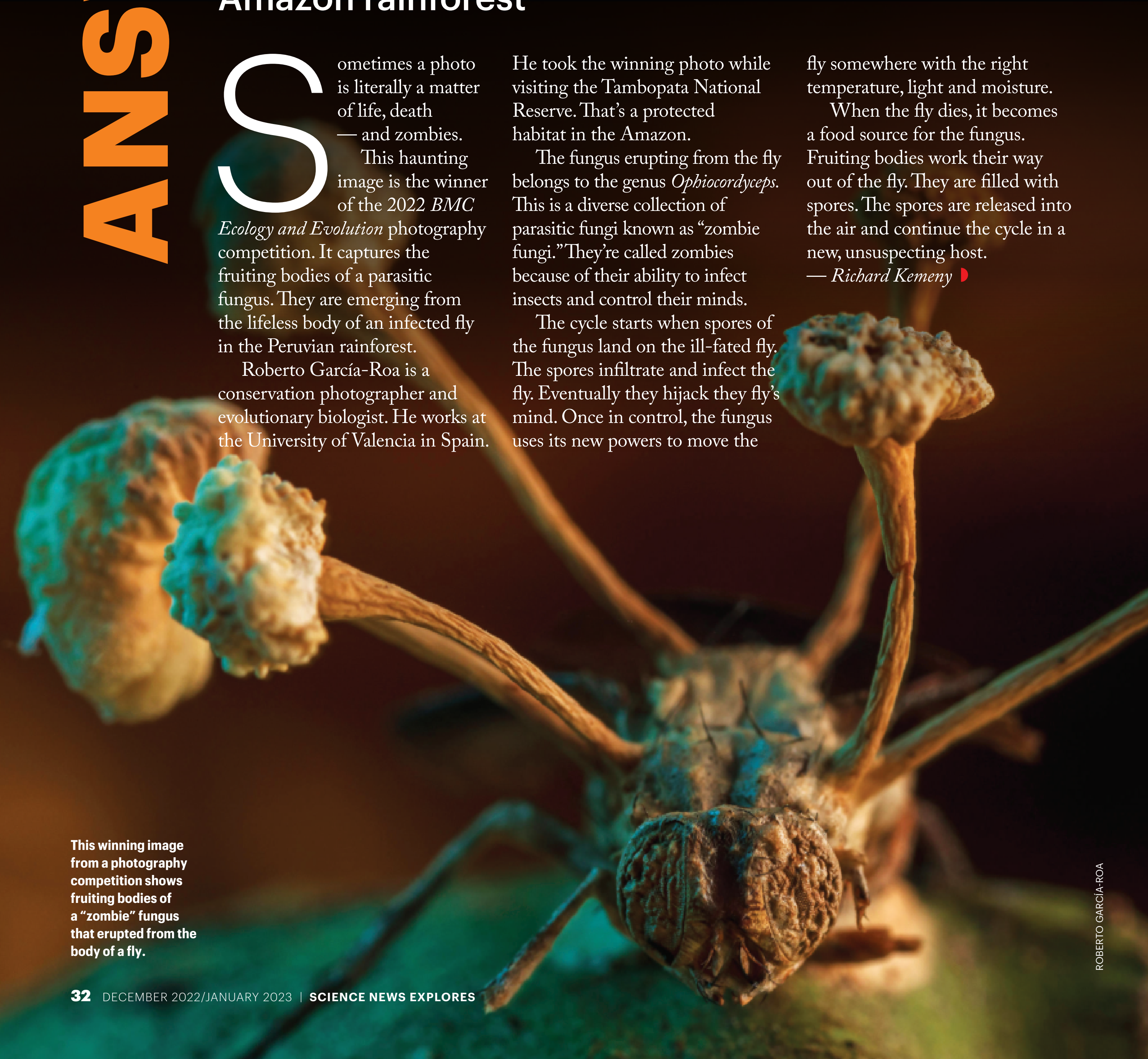
Roberto García-Roa is a conservation photographer and evolutionary biologist. He works at the University of Valencia in Spain. He took the winning photo while visiting the Tambopata National Reserve. That's a protected habitat in the Amazon.

The fungus erupting from the fly belongs to the genus *Ophiocordyceps.* This is a diverse collection of parasitic fungi known as "zombie fungi." They're called zombies because of their ability to infect insects and control their minds.

The cycle starts when spores of the fungus land on the ill-fated fly. The spores infiltrate and infect the fly. Eventually they hijack they fly's mind. Once in control, the fungus uses its new powers to move the fly somewhere with the right temperature, light and moisture.

When the fly dies, it becomes a food source for the fungus. Fruiting bodies work their way out of the fly. They are filled with spores. The spores are released into the air and continue the cycle in a new, unsuspecting host.

— *Richard Kemeny*



This winning image from a photography competition shows fruiting bodies of a "zombie" fungus that erupted from the body of a fly.

ROBERTO GARCÍA-ROA

Turn your hobby into a seriously cool science project

Here's advice from a winner of Broadcom MASTERS — the middle school competition of Society for Science

When you picture doing a science project, you might imagine peering through a microscope or building a model volcano. But science can be done anywhere and investigate just about anything. Like many teen science fair competitors, Elizabeth Shen found her inspiration in a hobby.

Q What inspired you to do this project?
A "As long as I can remember, I've been an artistic person," Elizabeth says. "In fourth grade, my art teacher taught us about the golden ratio. And at that point it was just, you know, something to use when we were painting." But last year, Elizabeth had to replace the memory in her own computer. Her dad told her about how computers write data unevenly across memory devices. Elizabeth realized the golden ratio might work in tech, too. "It wasn't like an 'aha' moment," she says. "It was just … 'Huh. This might be cool to explore.'"

Q What was your favorite part of this project?
A "Probably the experiments," Elizabeth says. She tested her golden-ratio technique by running programs on a computer. But before this project, Elizabeth had no coding experience. To prepare, she spent months reading a textbook on how to code. "Writing algorithms is such a tedious process," she says. "It was just cool to see all of those hours pay off and see the computer actually just doing stuff that I told it to do."

Q Any advice for science fair newbies?
A "Don't limit yourself," Elizabeth says. "One of the biggest challenges I faced was changing my mindset. I had always thought of myself as a more … writing, artsy person. I never thought that science or computer science would be my kind of thing." But after learning a bit about programming, "I found that it was actually something I could connect back to what I was familiar with: the arts," she says. "It was just a new way to express myself. Words, painting, now programming."

Winner of the 2022 Marconi/Samueli Award for Innovation

Elizabeth Shen

Elizabeth, 14, designed a new way for computers to store data. Her method is based on the golden ratio. This ratio is often used to create pleasing proportions in artwork. The ratio also appears in nature. The pattern of flower petals follows the golden ratio. The arrangement exposes petals evenly to sunlight. Likewise, Elizabeth's data storage strategy helps computers write data evenly across memory devices. This could help such devices last longer. Elizabeth is in eighth grade at Davis Drive Middle School in Cary, N.C.

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